

UTILIZATION OF COMPRESSED NATURAL GAS IN NIGERIA: A CASE FOR NATURAL GAS VEHICLES.

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ABSTRACT

This paper discusses the utilization of compressed natural gas (CNG), as an alternative to the traditional automotive fuels. Two main issues that make the topic important are; environmental and fuel pricing considerations. Other issues include; regulatory requirements, safety, affordability, vehicle stock, distribution network, and market size. These issues were discussed elaborately, and comparisons were made with different countries of the world, thereby highlighting the Nigerian situation. Finally, based on our abundant natural gas resource, and from its prospect as a supplement and an alternative to fossil fuel, CNG is projected as another alternative to conventional fuels, that is PMS and diesel.

KEYWORDS: compressed-natural-gas, issues, pricing, prospects, regulations, sustainability.

INTRODUCTION

Methane as the major constituent of natural gas, issues from the ground in great quantities in certain parts of the world. It can also be produced during the decomposition of plant matter in the absence of air. Methane is also given off from swamps and is often known as “marsh gas”. It is usually prepared by heating anhydrous sodium ethanoate with an alkali, usually soda-lime.

Therefore, compressing methane gas implies compressing a natural gas, hence the acronym CNG for compressed natural gas. CNG is less than 1% of its volume at standard atmospheric pressure, (Wikipedia 2010). It is stored and distributed in hard; thick containers or tanks at a pressure of 200-250 bar (2900 – 3700psi), and sealed to prevent spills or evaporative losses.

UTILIZATION/TOP CNG CONSUMERS

CNG finds its utilization in numerous areas. On a small scale, CNG is used domestically in homes for cooking. But in this paper, CNG’s commercial and technical use is extensively discussed, with particular emphasis on automobile use. The following countries of the world are among the highest consumers of CNG; Russia (610mscf/d), USA (604BMscf/d), Iran (98.19BMscf/d), Germany (96.84BMscf/d), Canada (92.76BMscf/d), United Kingdom (91.16 BMscf/d), Japan (83.67BMscf/d), Italy (82.64BMscf/d), Ukraine (73.94BMscf/d), and Saudi Arabia (68.32BMscf/d). Pakistan, Argentina, Brazil, and India are also major users of CNG.

HISTORICAL OVERVIEW

Use of Natural Gas (NG) as a vehicle fuel has had a long history dating back to the mid 1920’s. The two oil shocks in 1974 and 1979 and the possibility of renewed conventional fuel shortages, helped focus interest on Natural Gas vehicles (NGV’s). More recently, urban and global pollution have been recognized as serious problems, and this, has stimulated further interest in alternative fuels, including CNG. Alternatives, can broadly be considered in two categories; those which serve as replacements for conventional fuels, examples being LPG, CNG or dimethyl-ether (DME), and those which are blended with conventional fuel, for example alcohols, or biofuels. Italy developed interest in NGV industry in the 1930’s which has grown steadily. Argentina started later, and has grown to be one of the world’s leading countries for NGV’s and related refueling stations. On the other hand, in New Zealand, the CNG industry developed fast for about eight years, up to the stage where in 1987, 11% of passenger cars were converted to NGVs, however, the government changed its fiscal policies on CNG relative to liquid fuels, currently resulting in negligible growth of automotive CNG. A French man, Etienne Lenoir built a gas vehicle, (Wikipedia 2010), before the first PMS and diesel engine vehicles were developed. However, it took another 130 years, for the first compressed natural gas car to be produced as a serial product. Volvo was the first company to offer natural gas cars as serial products and Volvo’s first compressed natural gas car came into the market in 1997. Since 2001, the redesigned models – V60, V70 and

V80 have been available as natural gas versions with under-floor gas bottles. In 2000, Fiat was the first company to offer a compressed natural gas car (again with under-floor gas bottles) as a serial product that provided the same indoor car volume and comfort as the equivalent PMS vehicle. Currently, several vehicle manufacturers make different brands that run exclusively on CNG. At the present, CNG provides fuel for more than eleven million vehicles on the road, with Pakistan alone accounting for about 2.2 million Natural Gas Vehicles (NGVs). Until recently, Argentina accounted for the maximum population of NGV's in the world, but was overtaken by Pakistan in 2009. NGV statistics for the top five CNG consumers in the world are summarized in figure 1. (www.worldcng.com). The authors' choice to discuss briefly the following developing countries is to bring out some facts relevant to the utilization of CNG in Nigeria.

Pakistan

Pakistan is often referred to as a 'gas-based economy', as natural gas accounts for about 48% of the primary energy mix in Pakistan. In 2008, CNG sales in Pakistan stood at 198 MMscf/d and accounted for about 6% of the total gas consumption in the country. Pakistan is the world's largest CNG market and has registered a blistering annual growth rate of 60% p.a. over the last decade. In 2000, there were only 50,000 natural gas vehicles (NGVs) in Pakistan, while the current NGV population is over 2.2 million. (*Rijkeboer et al, 1994*). The key factors that have supported the growth of CNG in Pakistan, are strong government commitment, (to education and research), a liberal licensing regime for setting-up CNG outlets and widespread availability of natural gas, through a well-established pipeline distribution network.

Argentina

Argentina has the second largest NGV population (NGV's and related refueling stations) in the world. CNG sales (250MMscf/d) account for about 6% of the total gas demand (4.2cf/d) in the country. Argentina launched its CNG vehicle program in 1984. (<http://www.cleanairinitiative.org/portal/system.html>). The government offered no subsidies, instead the incentive for fuel switching stemmed entirely from the high tax on PMS. Then, at prevailing prices, the payback period for those vehicle owners converting from PMS to CNG could be a matter of months, depending on the total number of kilometers traveled a year. Growth in CNG sales was partly attributed to a well-established pipeline distribution network (over 90,000km), a widespread retail network, and a flourishing industry for local manufacturing of CNG equipment. (<http://www.fuel.gov.nz>)

India

Current CNG sales in India are estimated at about 190MMscf/d. The development of new deepwater gas fields on the Indian South-east coast has increased gas availability in India substantially. The government has earmarked an additional 250MMscf/d of gas from these new discoveries for sale to companies developing CNG projects, a move which could effectively double the size of the current NGV market in India. (<http://www.ign.org/woc1finalreport.pdf>)

So, in recent decades, significant contributions towards improved mobility have been made along the following lines as sustainability is pursued:

- Global and local availability of different types of fuels and their supplies
- Effort to increase efficiency of fuel and vehicle technology systems
- Effect of vehicle transport on local air quality, and global air quality.

Hence, the 20th and 21st centuries have been the golden age of mobility, underpinning economic growth in many countries of the world.

NIGERIA'S POSITION

The Nigerian business environment and policy makers need to be stimulated towards the environmental and economic opportunities inherent in penetrating the large Nigerian vehicular market, with a view to utilizing alternative fuels. Development of CNG as vehicular fuel in Nigeria was first proposed in 1997. Since then, several pilot projects have been implemented, with varying degrees of success. Following the partial deregulation of fuel prices in the country, and part removal of subsidy of refined products, CNG as alternative automotive fuel is very attractive from both the consumer and supplier perspectives. CNG for vehicular use was introduced into Nigeria by NGC (Nigeria Gas Company) in 1989, with two small compressors and dispensers installed in Warri and Lagos and 25 vehicles converted to run on natural gas. The project was noted to be a "success" with the only downside, being the unavailability of CNG refueling stations as was encountered by Brazil. In 1996, Delta Glass acquired CNG facilities and converted five of their forklifts to run on gas.

Additional catalysts for the CNG project were premised on deregulation of fuel prices in Nigeria and the removal of subsidy of refined products. A number of high pressure (200 bars) gas bottling and handling companies such as Air Liquid and Industrial Gasses Ltd, were recognized in Nigeria. (Nylund, 1996). NIPCO is currently diversifying into CNG refilling facilities and is in partnership with NGC for the deployment of CNG facilities in Nigeria. Benin was selected as the pilot town for the implementation of the CNG project, although it is planned to extend the project to Kaduna, Port-Harcourt, Lagos, Warri and Abuja. The partnership agreement requires that NGC will be responsible for providing the required gas for the CNG project. NIPCO plans to deploy CNG refilling facilities in Benin in two phases; phase 1 entails the construction of the gas distribution network and CNG refilling stations. The phase 1 of the project has been completed, and NIPCO is also setting-up bi-fuel vehicle conversion and servicing stations in Benin, though the long-term strategy is to handover this aspect of the business to locals. From 1989 till date, a number of international oil companies have carried out CNG studies and made attempts at 'operationalizing' CNG with respect to their Nigerian operations. With the few facts presented above, Nigeria is yet to make a mark as seen in Fig.1 (Watt, 2000)

1. ENVIRONMENTAL CONSIDERATIONS

The concentration of regulated and unregulated components in the exhaust gas of a CNG vehicle depends strongly on the engine/combustion type and the technology level of the CNG vehicle system. The ranking of emissions from CNG vehicles in the following sections is in comparison with PMS and diesel as provided for the various vehicle age groups. (See Fig.2) Figure2 deals with passenger cars from the mid-1970s and therefore gives an indication of emissions from vehicles with old PMS technology converted to CNG. It can be seen, that switching to gaseous fuels (CNG) contribute to a reduction of regulated emissions for old technology passenger cars. (Nylund, 1996). Figure3 shows that CNG converted passenger cars from the early 90s still have advantage over 3-way catalyst equipped gasoline vehicles in terms of carbon-monoxide (Co), but Nitric-oxide (NOx) emissions are similar. However, HC (hydrocarbon) emissions from the converted CNG vehicles are already higher for these examples compared to PMS and PLG. HC emissions from CNG cars consist mainly of methane which is difficult to convert over a standard 3-way catalyst; it shows that a special CNG catalyst would be needed to reduce total HC emission (Rijeober, 1994)

From figure 4, it is clear that CNG vehicles deliver the lowest emissions. Additionally, CO₂, methane and nitrogen (II) oxide (N₂O) are the main greenhouse gases which contribute to global warming.

2. FUEL PRICING ISSUES (ECONOMIC BENEFITS OF CNG UTILIZATION)

For the entire CNG development to be viable, each segment of the chain must be viable in its own right. For this reason, the economics of CNG supply is considered solely. Gasoline gallon equivalent (GGE) is the amount of alternative fuel it takes to equal the energy content of one gallon of PMS. GGE allows consumers to compare the cost of competing other fuels against PMS. (Gainsborough, 2001). One GGE of natural gas is approximately 126. 67scf and this volume of natural gas has the same energy content as one US gallon of PMS.

Analysis: with a 2011 Honda civic sedan.

The car model under analysis has 13.2 imperial gallon PMS fuel tank capacity. Energy content of 1 imperial gallon of PMS=150,000 BTU (studied) and 1 gallon of PMS=4.5 liters (standard)

$$\therefore 1 \text{ liter} = 0.222 \text{ gallon} \times 150,000 = 33355 \text{ BTU}$$

$$1 \text{ BTU} = 0.252 \text{ kilocalories (standard)}$$

$$\therefore 33355 \text{ BTU} = 8405 \text{ Kilocalories.}$$

Hence, 13.2 gallon PMS tank capacity = 59.4 liters x 8405 = 499,257 kilocalories.

But with CNG:

13.2 imperial gallons = 8GGE (3.8litres) tank capacity.

Energy content of 1scf of CNG = 1000BTU (standard)

1scf of CNG = 0.03 liters (standard)

$$\therefore 33.3\text{scf} = 33.3 \times 1000 = 33333\text{BTU}$$

1BTU = 0.252 kilocalories

$$\therefore 33333\text{BTU} = 8400 \text{ kilocalories}$$

Hence, 8GGE tank capacity = 3.8litres x 8400 = 31,920kilocalories

From the result, it could be seen that a full cylinder capacity CNG vehicle will use 467,341 kilocalories less than a full tank capacity PMS vehicle. A lot of polluting gases is also prevented from entering the environment and much money is saved. The economic benefits of CNG from the consumer perspective is viewed as follows; Assuming that there will be no tax incentive or subsidy for the consumer, the only driving force for convection is the difference in the cost of various fuels. With the consumer carrying out the conversion at US \$1.0 (~~₦~~150.00) per vehicle, the profitability indicators for the consumer are as follows:

The decision to convert a vehicle from PMS to bi-fuel is evaluated from the personal economic angle as follows:

The pump price of PMS (in Nigeria as January, 2011) = ~~₦~~65/liter

1 liter of PMS = 33,355BTU, this implies that price of PMS = ~~₦~~65/33355BTU.

∴ The pump price of PMS = ~~₦~~1, 949/mmBTU.

At a domestic gas price of \$2.0/mmBTU/mmscf 1scf of CNG = 1000BTU, this implies that; at a CNG sales price of \$2/1000BTU, domestic gas price = ~~₦~~300/mmBTU (at a \$:~~₦~~ conversion rate of 1:150)

If 59.4 liters of PMS = 1980scf (1.98mm/scf) of CNG, the gas price for filling a converted 2010 Honda civic sedan vehicle with CNG is 1.98 x 300 = ~~₦~~594, compared to an equivalent PMS Price of ~~₦~~3, 861.

As a standard, it is assumed that the CNG dispensing stations will be within 5 kilometers of existing gas pipelines, requiring no more than a 4 – inch gas supply pipelines, with a cost not exceeding US\$100. 00. Each station will have one compressor and three dispensers, each dispenser having two outlets (making the station capable of supplying six vehicles at a time). The total cost of the compressor and dispenser (including installation costs) will not be more than US\$2500.00 With each outlet in the station serving about 4 cars/hour, (32 cars per day) the daily gas sales per station will amount to 55mscf/d. For the above situation, the profitability indicators are as shown in table 1.

PROSPECTS

Generally, CNG utilization has a lot of prospects for countries that have realized the need, created the awareness, and made appropriate regulations. This paper looked at prospects with regards to; the environment, and economic benefits, before adapting the concept to the Nigerian society. Since the 1980s, environmental issues have had a rising impact on most human activities in most countries of the world. In comparison with such species of pollutants which act locally and directly on human health, CO₂ needs to be regarded more, in terms of their global impact.

Prospects to the Nigerian society

1. CNG as a “better alternative”

The major potential for growth of CNG in Nigeria lies in the vehicular market. In Nigeria, the economic situation is mainly driven by fuel pricing and scarcity of petroleum products, while fuel pricing issue is driven by the “excessive subsidy” required by the Nigerian government to maintain availability of key refined products. These situations highlight the need to further investigate the CNG alternative, for the Nigerian market. According to the Directorate of Petroleum Resource (DPR), Nigeria imports and consumes on the average, 13bln liters of PMS, annually. Also, between 2001 and 2010, Nigeria produced an annual average of 1.98m/n. The total PMS imported and consumed within Nigeria in 2009 is illustrated in figure 5.

Conversion of PMS engine vehicles to CNG is more profitable, if the converted vehicles become dual fuel (able to run in either PMS or CNG). Commercial vehicles (large fuel consumers), and stand to benefit the most from switching to CNG. Hence owners of large fleet of commercial vehicles will have to be approached and convinced of the need to convert to CNG. Although conversion of diesel engine vehicles is much more difficult and expensive. Therefore for heavy – duty vehicles, such as trucks and big buses, it is preferable to have these imported with natural gas engines. In summary today’s light-duty CNG vehicles are stoichiometrically controlled and use 3- way catalysis with natural gas sensors, which provide the feedback signals for gas injection. As with PMS engines, a sophisticated electronic CNG metering and engine management system, ensures precise fuel injection on demand. Modern light- duty CNG engines employ port injection and four–value cylinder heads to improve combustion efficiency.

2. Benefit to Nigerian Government

It has been established that, if 60% of the vehicles in Nigeria convert to CGN, the Nigerian government will save the foreign exchange required in purchasing 4.7bln liters of PMS, annually. This translates to saving approximately 42% of the foreign exchange, currently expended on importation of PMS.

Utilization of CNG in Nigeria – Recommendations

A number of issues are usually raised as possible obstacles to CGN development in Nigeria. These include; regulatory requirements, safety, vehicle stock, affordability, warrantee for converted vehicles, the pipeline distribution network and the size of the market. The recommendations for approaching and tackling these issues are offered below.

1. REGULATORY REQUIREMENTS (INVESTMENT STIMULATION)

It is recommended that a clear strategic plan to increase the share of natural gas in the Nigerian fuel mix, be put in place, by the government. This plan will then drive the investment awareness for the CNG. The key factors that are required to support the growth of CNG in Nigeria are; (i) strong regime commitment (ii) a liberal licensing regime for setting-up CNG outlets and (iii) investments in widespread availability of natural gas, through a well-established pipeline distribution network. The eastern and western domestic gas network can be expanded, prior to the implementation of the national gas master plan. Additional government policies such as waving of custom duties on the importation of CNG machinery and equipment, like conversion kits and cylinders, or tax holidays are also hereby recommended.

2. SAFETY REGULATIONS

Countries that have adopted CNG have enacted extensive technical and safety standards for both CNG vehicles and development of CNG supply stations. Standards have already been established for design and for materials required for various components of the CNG fuel system, installation and maintenance of CNG cylinder and kits. Also, for regulation regulation for design and development of CNG filling stations, compression and dispensing equipment and for vehicles for bulk transport of CNG, etc. It is recommended that these regulatory requirements be adapted to the Nigerian situation.

(a) Fire hazard: generally, the fire risk associated with gas is more related to those identified with domestic LPG that is more commonly used in Nigeria. Actually as shown below; CNG possess less fire hazard compared to PMS or LPG:

- Being lighter than air, natural gas leaks will rise and disperse, not forming puddles as PMS, or spread close to the ground as LPG.
- Ignition temperature is much higher (600⁰C) than in PMS, making it more difficult to Ignite.
- Ignition requires a high concentration in air, which is not easy to achieve even with a leak.
- Natural gas will only burn if its concentration in air is between 5% and 15%.

(b) High pressure: The fact that CNG is gas bottled at 200 – 250barg, poses the risk of high-pressure explosion, if not properly handled with care. In order to mitigate this, CNG bottles are usually tested to between 350 and 500barg, thus making an allowance for thermal expansion of the gas if the bottle is subjected directly to fire. In addition, the CNG bottles in vehicles are fitted with pressure release valves to prevent explosion of the bottle.

3. VEHICLE STOCK

As highlighted above, most of the vehicles used for public transport in Nigeria, have been used elsewhere before they were brought into the country, however, the bulk of these ‘second – hand’ vehicles are used in transportation within the city. Inter – city transport vehicles tend to be newer. Therefore, conversion to CNG is generally recommended for vehicles not older than ten years. One way of tackling this is to encourage vehicle dealers to import factory – fitted CNG vehicles or offer top CNG convert vehicles as part of their sales service. With this, it is envisaged that the bulk of new vehicles coming into the country will be equipped with CNG facilities.

4. AFFORDABILITY

Most of the vehicles used for public transport in Nigeria are privately owned, with each person having one or more vehicles. Furthermore, most of these were bought as used vehicles at prices, in the range of US \$2,000 to US \$15,000. It is assumed that such owners cannot afford to invest another US \$1,000 to convert their vehicles

to CNG, given that the pay-back time would be less than two years. A possible way around this problem is for the company that is marketing the CNG to prepare a vehicle conversion package that would be attractive to the vehicle owner and allow the gas seller to recover its contribution to the vehicle conversion cost.

5. VEHICLE WARRANTY:

Since CNG has not been introduced on a large scale in Nigeria, there are few factory fitted CNG vehicles in Nigeria. This means that to run on CNG, all vehicles imported or manufactured in Nigeria, will have to be retrofitted with CNG facilities. Such conversion could lead to a situation where the dealers withdraw their warrantee. One way round this is to involve the manufacturers, or their representatives in Nigeria, in the conversion process. Use of world renowned vehicle conversion companies in the conversion process in Nigeria; will go a long way in carrying along the vehicle dealers.

6. PIPELINE DISTRIBUTION NETWORK The gas pipeline network to which CNG dispensing stations have to be tied, currently exist only in the southern part of the country i.e. the eastern and western domestic gas network. Initially, this will limit availability of CNG dispensing stations. Apart from extending the pipeline network and implementation of the Nigerian gas master plan, one of the ways to be considered, should be hauling large quantities (0.2mmscf CNG or 0.8mmscf LNG) of, gas by railways to dispensing stations in the north, or to places, remote from the pipeline network.

CONCLUSIONS

Admittedly, despite the issues, problems and challenges in developing CNG usage in Nigeria, there are prospects of; sustainable environmental and economic benefits for both Nigerians and the Nigerian government that can be derived, beyond what has been reviewed by this paper. However, the key points to note here are:

- Beside the environment benefits provided by CNG utilization, developing the Nigerian CNG industry will be a profitable business.
- CNG development for vehicular use in Nigeria has the potential to create jobs, and a large market for gas, thereby providing alternatives to PMS usage and saving foreign exchange for the Nigerian government.
- Developing the CNG industry in Nigeria will ensure that the spectre of fuel scarcity in Nigeria, is finally laid to rest, as Nigeria has gas reserves in abundance, of which only a fraction is required to sustain the country's CNG industry.
- Sustained strategic drive is required from our policy makers, to generate the initial momentum required to develop the CNG industry, by ensuring the following:
 - i) Demonstrating a strong government commitment towards the development of CNG in Nigeria.
 - ii) Increasing investments in widespread availability of natural gas, via the expansion of the Eastern and western domestic gas Networks.
 - iii) Waiving or reducing custom duties on the importation of CNG machinery and equipment.

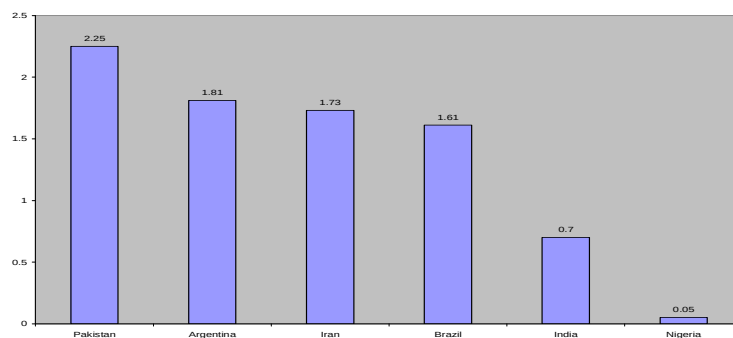


Figure 1: NGV statistics - January 2010- Source: Gas Vehicles Report, NGV Global

A) Older technology (non-catalyst passenger cars)

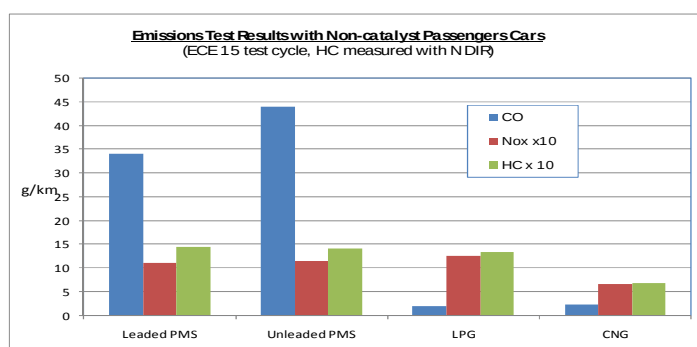


Figure-2: Emission Test Results with mid-1970's vehicles. Source (Mr. HEMI's Auto Emissions-Testing/101)

B. Catalyst vehicles (early 90s models)

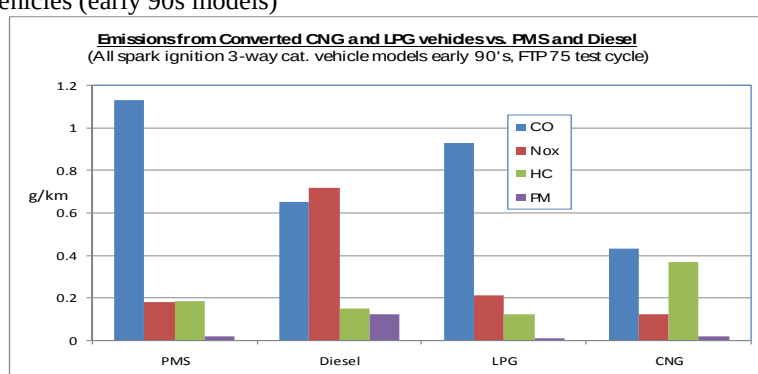


Figure-3: Regulated emissions Comparison for 90's vehicles. Source: (eidr.wvu.edu/eidr/documentdata.eIDR)

EMISSIONS COMPARISON FOR 2003 – 2010 VEHICLES

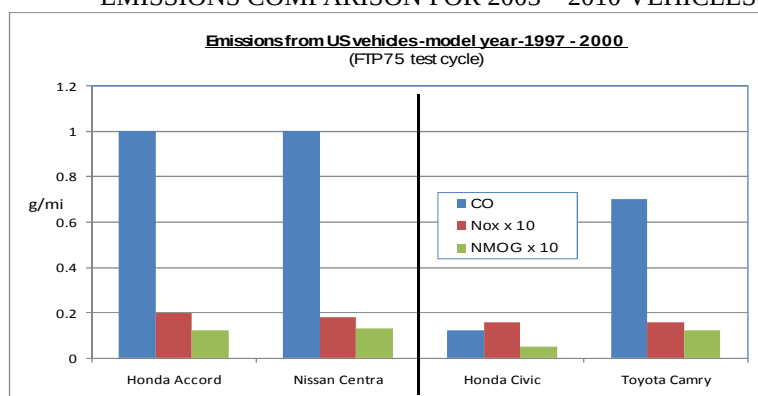


Figure-4: Regulated emissions Comparison for 1997-2004 vehicles. Source (www.epa.gov/airtrends)

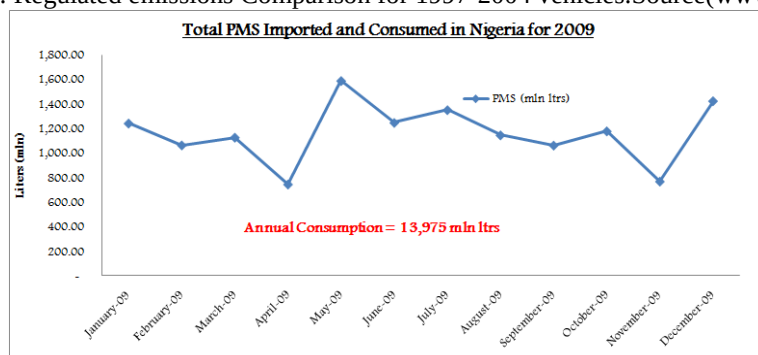


Figure-5: Total PMS imported and Consumed in 2009- Data from Directorate of Petroleum Resources

Table 1: Daily Gas Sales of a CNG Station

Gas purchase price	Gas sales price	Gas dispensing rate	Capex	Pay back time (capex/gas purchase price)
\$/mscf	\$/mscf	Mscf/d	US\$m/n	Years
2.0	5.0	55	0.35	6
2.5	5.0	55	0.35	7
3.0	5.0	55	0.35	9

- Please note that the costs used are indicative

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